

### 3.1.10. SURFACE RADIATION

#### *Solar and Terrestrial Atmospheric Radiation*

The surface radiation budget (SRB) is a basic and critically important climate variable that has long been inadequately observed because of insufficient global coverage and inherent instrumental limitations. Surface-based radiation monitoring projects are being carried out by CMDL at eight locations: BRW, Erie and Boulder, Colorado (BAO and BLD), Bermuda (BRM), MLO, Kwajalein, Marshall Islands (KWJ), SMO, and SPO. The long-term continuous measurements at these sites include broadband downward solar irradiances and several sites, BRW, BAO, BRM, KWJ, and SPO, also measure downward thermal infrared irradiances. At sites where the measurements were determined to have a representative surface (BRW, BAO, and SPO) upward solar and infrared irradiance measurement projects are also maintained. The more extensive observations are made at CMDL sites where the measurements are more areally representative especially with respect to land surface and cloudiness. Irradiances observed at the more areally representative sites, BRW, BAO, KWJ, BRM, and SPO are being incorporated into an international data base sponsored by the WMO and NASA under the Baseline Surface Radiation Network (BSRN). All data from CMDL sites are also maintained as part of the long-term CMDL surface radiation record that exists for the past 15 years at BRW, MLO, SMO, and SPO. Previous CMDL (and GMCC) Summary Reports have discussed the wide ranging and useful applications of these data to scientific questions.

Recently completed and ongoing projects utilizing the radiation observational results from the CMDL field sites include the detection of a long-term decrease in Arctic haze [Bodhaine and Dutton, 1993]; comparison of satellite and BAO-derived SRB under clear and cloudy conditions [Cess *et al.*, 1991, 1993, 1995]; the effects of snow surfaces on atmospheric absorption [Nemesure *et al.*, 1993]; detection of intermediate-term trends in cloudiness related to radiation perturbations [Dutton *et al.*, 1991; Schnell *et al.*, 1991]; a technique for monitoring long-term climate variability using surface albedo records [Dutton and Endres, 1991; Foster *et al.*, 1992]; identification of a strong statistical coherence between the QBO and the MLO long-term transmission record [Dutton, 1992a]; a surprisingly good agreement between modeled and observed thermal infrared irradiances over the range of globally extreme conditions [Dutton, 1992b], and a determination of the radiative effects of the Mt Pinatubo volcanic eruption [Dutton and Christy, 1992; Russell *et al.*, 1993, and Dutton *et al.*, 1994]. Dramatically new information on cloud absorption is being revealed in an ongoing investigation using CMDL surface and satellite top-of-the-atmosphere solar data, Cess *et al.* [1994]. Numerous additional requests were made and fulfilled for CMDL radiation data for a variety of research applications.

Updated results on the late summer cloudiness and irradiance trends at SPO reported by Dutton *et al.* [1991] are shown in Figure 3.15. As suggested by Dutton *et al.* [1991], the previously observed trends during January and February until 1988, did not project into the future. The current SPO irradiance level shows an autocorrelated return to previous levels. The potential for a >20-year oscillation in these data now exists.

The MLO atmospheric transmission record, updated through 1993, is shown in Figure 3.16. The effects of the eruptions of Mt. Pinatubo and El Chichon are most obvious and are enlarged and compared in the inset of the figure. This record is now continuous for the past 37 years and may provide the best available information on the lack of any significant secular trends in the global background atmospheric transmission of solar radiation over this time. Two to three more years without a major volcanic eruption will be required for the record to once again reach its background level.

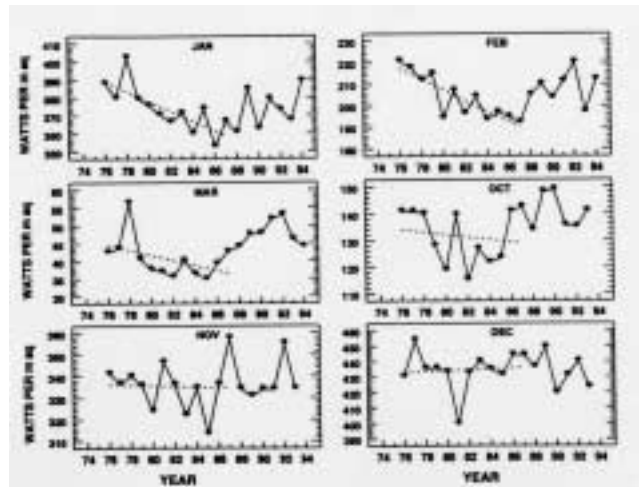


Fig. 3.15. Monthly mean total (direct plus diffuse) solar irradiance at the South Pole. The plotted lines are for linear least-squares fits for 1976 through 1987.

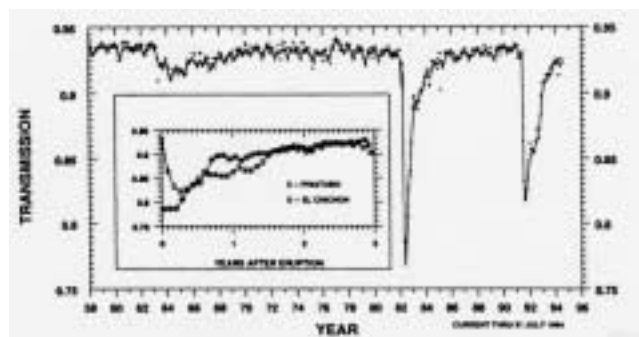


Fig. 3.16. Monthly mean "apparent" atmospheric transmission as determined from broadband direct solar beam observations at Mauna Loa.

Snowmelt date at Barrow, Alaska, was defined as the last date each year that any significant snow remains on the ground (first day each year that <1 inch of snow is reported in visual observations or the daily average surface albedo falls below 30%). Considerable differences between the NWS observations within the village of Barrow and on the tundra near the CMDL site were noted in Figure 3.17. When compared with other tundra albedo data for the late 1960s and early 1970s and the earliest NWS data, the CMDL data [Dutton and Endres, 1991] continue to suggest that there was no significant change in the annual date of spring snowmelt near Barrow since the 1940s. The NWS data [Foster, 1989] alone suggest an advancing date of snowmelt that can be interpreted erroneously as being due to a general warming, but is instead most likely because of urbanization of the Barrow village.

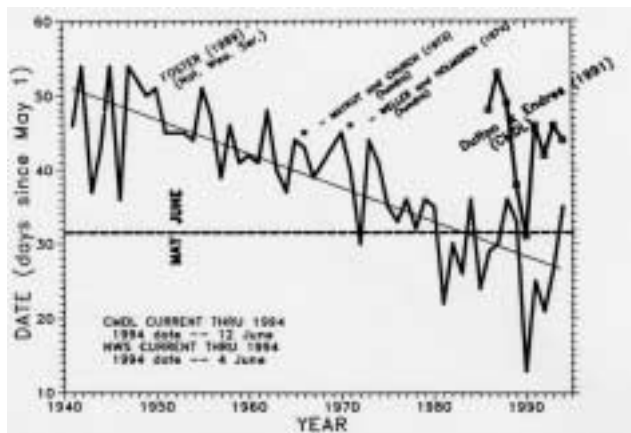


Fig. 3.17. Date of annual spring snowmelt as determined by various researchers at different locations in and around Barrow, Alaska. The downward trend indicated by the Foster (NWS) curve is believed to be due to "urbanization" in Barrow.

The CMDL radiation project accepted the responsibility of working with the WMO GEF/GAW program for the intent of establishing a surface-based solar radiation measurement and research program at each of four global baseline sites located in developing countries. CMDL will acquire the necessary equipment, train onsite observers, and assist in the establishment of programs in Algeria, China, Argentina, and Indonesia over the next 2 years.

### Operations

There were only a few significant changes in observatory operations during the year, which is an important attribute of a long-term measurement effort. Blowers were added to the upward facing pyranometer and pyrgeometer at SPO. The new units are very effective in keeping frozen precipitation and condensation off the filter domes. Additional blower units are being acquired as funds allow for implementation at other sites. A critical requirement of the radiation project is

to make stable and accurate micro-volt level measurements to ensure that the potential voltage measurement error is small compared with other sources of error. Current data loggers have integrating A/D converters with auto zeroing and achieve 2 microvolt accuracy. Continuous data logging at all eight sites now has 3-minute or better resolution recorded and permanently stored. Data sampling times range from 1 to 2 seconds.

Incoming data are currently received daily in Boulder for all sites except SMO, are processed within 2 days, and reviewed for quality-control purposes. Data editing, processing, and final storage have been moved to medium-sized and personal computers all directly under the control of CMDL, thereby eliminating the dependence of outside computer expertise and resources. Final processing is completed about 1 calendar year after the data are first available for processing. Assignment of final calibration information is ongoing as updated radiometer calibration data are made available. Final data values depend on careful review and application of sensor calibration information that is provided by the CMDL Solar Radiation Facility.

### Remote Sensing of Aerosol Optical Properties and Water Vapor

Other than clouds, aerosols and water vapor are the main contributors to thermal-infrared and solar radiation variations and subsequent radiative climate forcing. The potential climate variations resulting from such variations are extensive and varied. The observed and potential radiative variations may be due to either anthropogenic causes such as increased industrial production of aerosols and water vapor feedback resulting from increasing greenhouse gases or from natural causes such as volcanic, biogenic, or surface wind-generated aerosols and inherently varying water vapor. CMDL has a long history of exploratory and operational projects relating to the remote sensing of aerosols and water vapor as related to climate variations. Since 1977 wide-band spectral observations of direct solar irradiance using a filter wheel NIP at BRW, MLO, SMO, and SPO were used to infer aerosol optical depth and column water vapor amounts. These measurements have proven to be durable and stable over time thereby excelling in a monitoring effort even though their accuracy is less than can be obtained by more sophisticated but less robust instrumentation. Additional and exceptional effort has been put into high-precision narrow spectral band optical depth measurements at MLO. At MLO several narrowband (0.005  $\mu\text{m}$ ) sunphotometers are routinely operated and, because of the nearly ideal atmospheric conditions and the existence of automated observing platforms, have produced reliably consistent long-term data sets. Results from the MLO aerosol optical depth measurement project are reported by Dutton *et al.* [1994] and Russell *et al.* [1993] and in previous CMDL Summary Reports. One year of narrowband sunphotometer data were collected from Sable Island, Nova Scotia, as part of a comprehensive surface-based aerosol sampling project described in section 3.1.1.2.